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TRIFFID — the British Army's new tactical u.h.f radio relay equipment

Summary

U.H.F radio relay, with its high traffic capacity, its directional transmissions and its compact antenna heads continues to meet the needs of the military user in the tactical setting. The increasing constraints on frequency availability have been a major factor in the British Army's decision to replace its three in-service v.h.f and u.h.f radio relay equipments with TRIFFID – Marconi Communication Systems Limited's transportable u.h.f radio relay equipment. This article discusses some aspects of TRIFFID's procurement, describes its component units and outlines its operation.

The military requirement

The Ministry of Defence requirements for TRIFFID were, as usual, particularly detailed and comprehensive and they stressed compatibility, flexibility and reliability. As the new generation radio relay equipment for the British Army's mobile tactical area communication system, TRIFFID was not only to be used in the present system BRUIN where it would replace three in-service equipments which were approaching the end of their useful lives, but it would also be used as the main bearer for PTARMIGAN due to begin introduction in 1983.

The conversion from one role to the other was required to be carried out without involving modification to the equipment. To this end the Line Terminating Unit and the Engineering Order Wire Unit have been designed specifically for BRUIN and will be exchanged for a PTARMIGAN Line Terminating Unit and Engineering Order Wire unit on conversion. The rest of the equipment is compatible with both systems. Three frequency ranges were demanded in order to ease the problems of frequency availability in a highly active electronic scenario. The TRIFFID equipment was also to be designed to meet EUROCOM standards in order to provide commonality and to enhance its overseas sales potential.

Procurement

As a result of competitive tender MCSL were awarded a package contract for the development and production of 450 equipments with options for an additional quantity. A further order for 400 equipments was recently placed taking up part of the option quantity.

The MCSL offer was based on the enhancement of an existing equipment, the Siemens/Telefunken FM 200. This involved some re-design of the existing FM 200 and the design and development of three additional units to meet the requirements of the British Army.

The contract was let with MCSL as the main contractor and with Siemens and Telefunken as major sub-contractors. In the development phase Siemens and Telefunken were responsible for the re-design and enhancement of the FM 200 units (*i.e* the Power Supply Unit, the Systems Module and the Band 1 and Band 2 RF Heads), while MCSL were responsible for the development of the three new units (*i.e* the Band 3 RF Head, the Engineering Order Wire and the Line Terminating Unit). For production, however, significantly more work was to be undertaken in the UK. Telefunken would continue to produce the Band 1 Head for TRIFFID and Siemens to produce about 50% of the Systems Module. MCSL are producing the remaining (and major) part of the TRIFFID equipment.

The production of items by MCSL previously developed in the Federal German Republic gives rise to many problems. The difficulties resulting from transference of any production activity to a point geographically remote from the development area are well known. MCSL are therefore paying considerable attention to initial production activities and to ensuring good liaison with the development team in the Federal German Republic. Following from this is the need to provide comprehensive production testing. This not only ensures that equipments meet the rigorous military standards initially, but also that they continue to meet them throughout production.

At the time of writing a number of B-model equipments together with their installations are undergoing comprehensive user trials under fixed conditions by serving soldiers based at the School of Signals in Blandford. The trials directive aims to assess the equipment not only as an isolated radio station, but also as part of a tactical communications system. It, therefore, includes exercises to trial TRIFFID'S interoperability with current in-service radio relay equipments including multiplexers, security equipments and combiners, as well as testing its performance in a mixed relay chain. Path loss capability is being tested as is the satisfactory simultaneous operation of all three sets in a triple installation (figure 1). A tactical evaluation is also included and this requires the set to be operated when dismounted from its vehicle as when mounted in a tracked vehicle. These trials have been notably successful to date.

Initial production activities have been commenced and the first complete installations are expected to be delivered to the Army during 1979.

General description

TRIFFID has been developed specifically for military tactical use and is of rugged design. It is for use in wheeled or tracked vehicles but can be quickly dismounted and used as a fixed installation in a building. It accepts digital traffic at 250, 256, 500, 512kbit/s, uses frequency modulation and can operate in the following radio frequency bands: 225–400MHz (Band 1) 610–960MHz (Band 2) and 1350–1850MHz (Band 3).

The original FM 200 equipment on which the TRIFFID design is based comprised four units, a Band 2 RF Head, a Band 1 RF Head, a Systems Unit and Power Supply Unit. These four original units have been redesigned and can be seen as the upper four units in the triple installation shown in figure 1. To these four have been added a further three units: a Band 3 RF Head (not shown in figure 1), an Engineering Order Wire unit and a Line Terminating Unit – right and left respectively mounted side by side at the bottom of each stack in figure 1. These seven units make up TRIFFID and all controls, connections and interconnections are taken away from the front faces.

Fully regulated supplies for all units are fed from the Power Supply Unit. The Systems Unit contains the baseband circuitry, modulators, de-modulators, and synthesizers for the transmit and receive paths. The System Unit generates and accepts the radiated frequency for Band 1 (225 to 400MHz) and Band 2

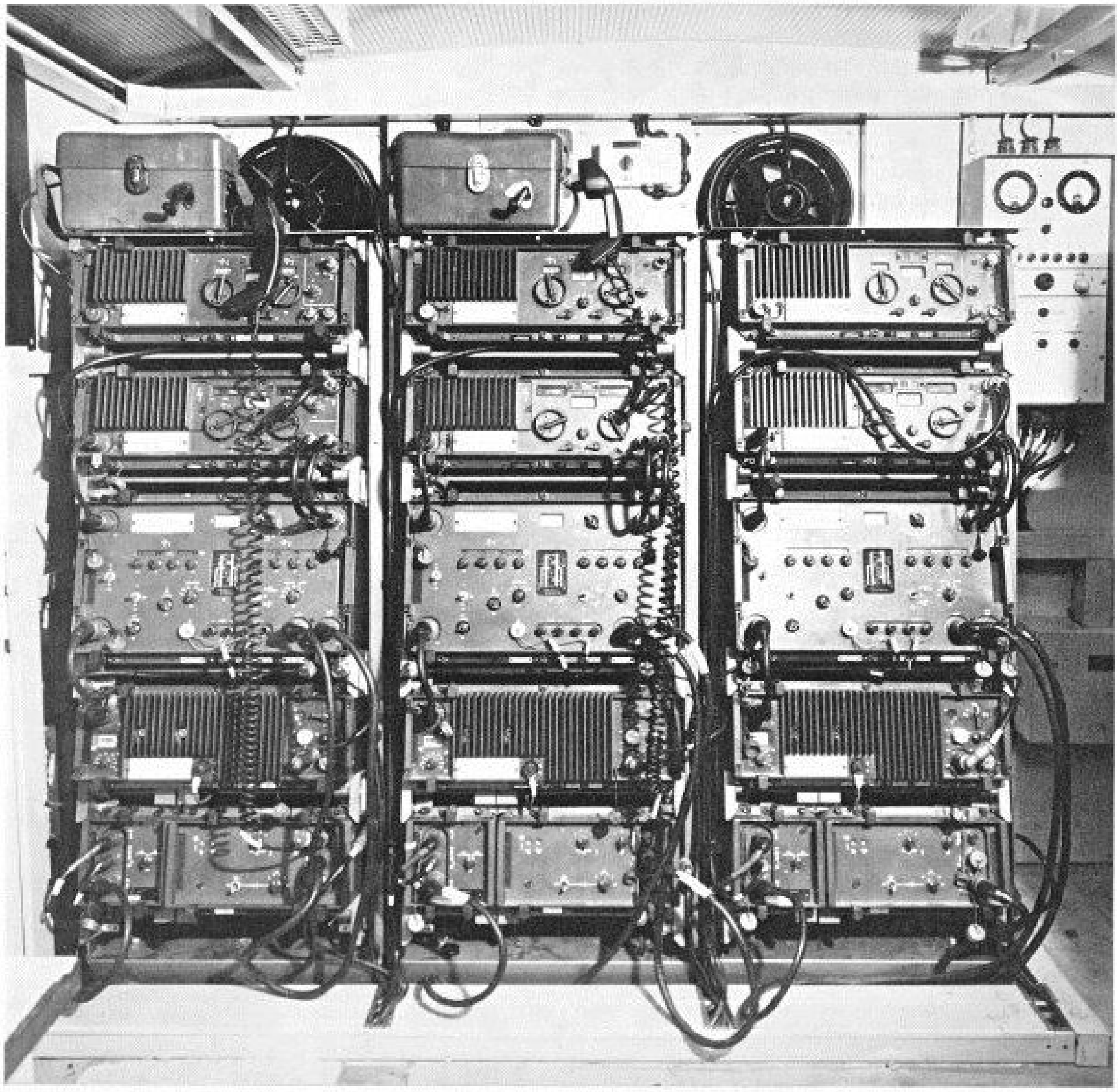

Figure 1. TRIFFID – triple mounted in the wheeled vehicle installation

(610 to 960MHz) operation. In Band 3 (1350 to 1850MHz) the Systems Unit is always set to between 300 and 400MHz and the final frequency conversion to the radiated frequency takes place in the Band 3 r.f Unit. There are separate transmit and receive connections between the Systems Unit and the RF Units.

Frequency setting is accomplished by setting the Systems Unit (transmit or receive) to the required channel frequencies and tuning the r.f unit to the same indicated frequencies. In Band 3 operation the Systems Unit is set to read the tens, units and fractions, of the required channel frequency and the full frequency is dialled up on the r.f Unit Band 3. Transmit output powers are 10W Band 1 and Band 2, 1.2W in Band 3. All output powers are reducible in steps over a range of about 10dB.

Description of individual units

POWER SUPPLY UNIT

The p.s.u is designed to operate from battery or mains and provides the various voltages – six in all – required by the other modules. The unit is capable of being connected to both mains and battery together and in this case the normal operation is from mains, the battery taking over automatically without interruption if the mains supply fails.

SYSTEMS UNIT

The Systems Unit is the heart of the equipment. It accepts traffic at the following rates, 250, 256, 500 and 512kbit/s. The rates of 250/500kbit/s are for BRUIN operations, and 256/512kbit/s are for PTARMIGAN and EUROCOM operation. The Engineering Order Wire input is digital with a 16kbit/s bit rate.

Transmitting

The e.o.w and traffic waveforms are added together algebraically before modulation. The sum signal is shaped in the pre-modulation filter before it is applied to the frequency modulator. The modulator output is at 50MHz, the mean frequency being controlled by a crystal referenced loop. The modulator output is fed directly to a phase detector where it is compared with a mixed-down version of the transmit frequency signal generated by one of a bank of phase-locked oscillators. The phase detector output voltage is used to control the phase-locked oscillator modulation. In this way the modulation is transferred from the i.f frequency to the radiated frequency. The downconverted frequency fed to the phase detector is generated by use of a local oscillator derived from the synthesizer which sets the transmit frequency via the front panel controls.

Receiving

The received signal from the RF Unit is double down-converted by direct mixing to a final intermediate frequency of 35MHz. After filtering this signal is demodulated by a phase-lock demodulator.

Traffic – e.o.w separation

The e.o.w is then separated from the composite base-band signal. At this stage the demodulated signal is a composite wave of which 80% of the voltage excursion is due to traffic at the traffic bit rate. Superimposed on this is 20% excursion due to the e.o.w signal at 16kbit/s. The e.o.w and traffic signals are separated by processing the composite signal in the time domain.

Firstly a rectangular waveform with the same zero crossings as the traffic is generated using a dual input level decision circuit. The level decision circuit is fed with a sample of the e.o.w signal from the output of the separator and the composite receive signal. Secondly, the composite signal, riding on a d.c voltage, is sampled with a narrow pulse at the centres of the traffic bits. To this sample is added the rectangular wave from above. The tips of the resultant waveform follow the e.o.w waveshape. Peak rectification of this waveform yields the e.o.w waveform. This waveform is subtracted from the original composite signal leaving the traffic waveform ready for regeneration. The e.o.w waveform itself is then regenerated to give a 16kbit/s bit stream.

BAND 1 R.F UNIT (see figure 2a)

The unit takes the transmit signal (225–400MHz) from the Systems Unit. After broadband pre-amplification a tuned transistor amplifier is used to develop the final 10W output level. This is passed via a tuned isolator to a two-section transmit filter. The antenna connection is taken off by a tee suitably positioned between the transmit and receive filters. Both transmit and receive filters consist of coupled, capacitively-loaded transmission lines. Tuning is accomplished by tuning the loading capacitance which is provided by a shaped vane. The receive preamplifier has a 5dB noise figure and the overall receive path gain is 17dB. The output of the receive preamplifier is connected to the Systems Unit through a single section image filter.

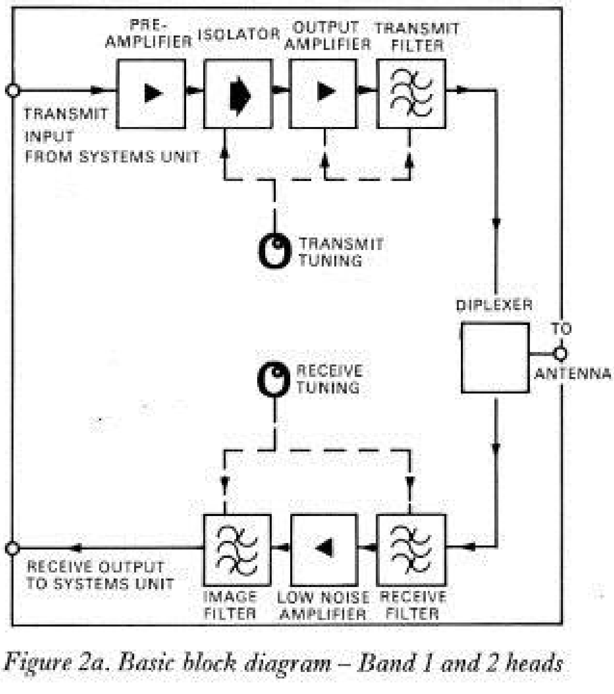

Figure 2a. Basic block diagram – Band 1 and 2 heads

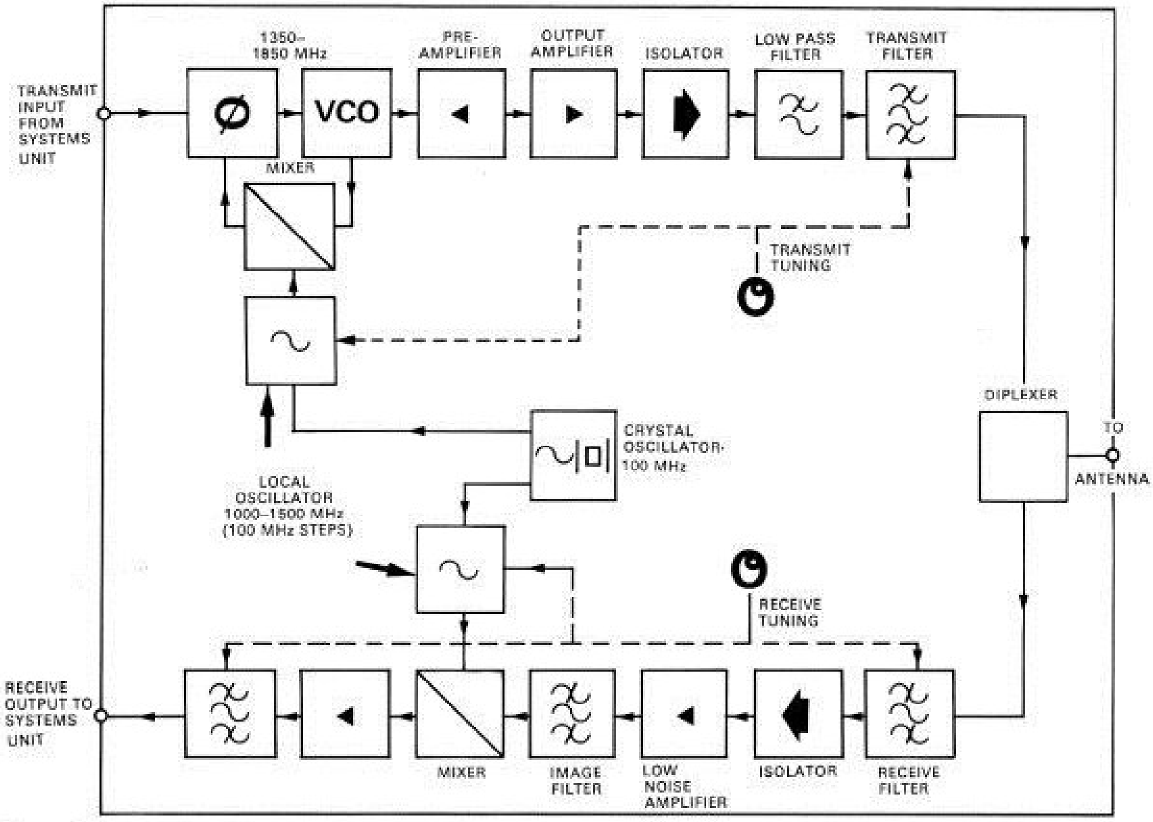

Figure 2b. Basic block diagram – Band 3 head

BAND 2 R.F UNIT

This has a similar block diagram to RF Unit Band 1. The transmit amplifier consists of two triode, tuned amplifier stages. The high voltage power supplies for the valves are contained within the RF Unit. Transmit and receive filters consist of open circuit coaxial resonators where the resonant line length is adjusted within a tapered outer to achieve tuning.

BAND 3 R.F UNIT (see figure 2b)

The Band 3 RF Unit is a more recent addition to the equipment stack and a need not to alter the earlier design of the Systems Unit more than necessary was one of the prime constraints on the design. Other allied constraints were that the frequency deviation was to be identical for all three bands and that the setting of the system frequencies on synthesizers and RF Units should be direct reading with no recourse to calculations or tables.

Frequency translation

The scheme which was adopted is that the Systems Unit synthesizers are set to operate between 300 and 400MHz with the hundreds window displaying the band three symbol (III). The tens, units and fractions of MHz windows display the required ten, units and fractions of the final radiated frequency. The Band 3 RF Unit displays the full radiated frequency. In the Band 3 r.f Unit translation to the final radiated frequency is accomplished by mixing the Systems Unit output with a local oscillator which spans the band 100MHz–1500MHz in 100MHz steps. The point of switching-in the next 100MHz step is determined coarsely by logic signals taken from the mechanical drives on the frequency control. This coarse information is refined by reference to exact band switching signals sent up from the Systems Unit synthesizer settings. Frequency translation of the 300–400MHz signal from the Systems Unit is carried out by mixing the feedback path of a phase lock loop whose oscillator is phase locked to run at the radiated frequency. This scheme is used in preference to direct mixing because it permits unwanted mixing products to be well isolated from the forward r.f signal path. The output of the phase locked oscillator bears the modulation and is at the final frequency. It is amplified in a two-module untuned r.f amplifier to a level of 4W.

Antenna diplexing

The antenna diplexer is built up from tuned transmit and receive filters connected to a broadband circulator. The transmit and receive filters consist of co-axial, quarter wavelength, cavities with aperture coupling. To tune the filter, bored-out dielectric cones, which fit over the end of the open-circuit inners, are moved over the resonators by a lead screw. The lead screw also operates the local oscillator band-switching and a transmit mute switch which acts when transmitter and receiver are tuned closer than 40MHz.

Receiver

The receive signal from the five-cavity receive filter is amplified in a two-stage low-noise amplifier, passed through the first image filter and mixed, using a stepped local oscillator, down to a 300–400MHz first i.f. The signal is then passed through a second image filter to the Systems Unit.

LINE TERMINATING UNIT (LTU)

This unit has been designed specifically for the requirement of BRUIN. It provides the interface between the System Unit and the BRUIN cable connection and replaces the reconstituter at present used in BRUIN. It can be located either directly with the radio equipment or separately within the radio vehicle. On the transmit leg the unit provides amplification, automatic level control and reconstitution of the incoming traffic signal from the line. It generates traffic clock pulses and provides the correct interface conditions for the System Unit. On the receive leg it re-forms and re-times the traffic signal and provides the correct interface conditions for the cable. The unit also facilitates connection of the field telephone for the phantom cable connection between facilities control and relay vehicle. Lightning protectors are fitted.

ENGINEERING ORDER WIRE UNIT (EOW) ('TALK-IN')

This unit has been designed specifically for use with TRIFFID in BRUIN. It has a delta modulator which converts the analogue input (from the handset) to a 16kbit/s digital stream. The unit is connected to the 16kbit/s channel in the System Unit specially provided for an e.o.w facility. The e.o.w unit provides speech and calling facilities for four stations (two terminal and two intermediate). Each unit is capable of being designated as station A, B, C or D using the front panel switch; the designation determines the signalling code to which the unit will respond. Calling is accomplished by operating a switch on the front panel. When using the handset, operation of the pressel switch at a relay station will break the through circuit and connect the local operator to both directions of the e.o.w circuit. In this situation, stations either side will still be able to call the station engaging the circuit. It should also be noted that, when used at an intermediate station, one unit will be connected to both TRIFFID equipments. The sizes of the e.o.w and l.t.u units have been chosen so that they can be mounted side by side, the dimensions of the combined units being equal to those of an RF Unit.

ANTENNAS

Three types of antenna will be used, one for each band:

(a) Band 1 (225–400MHz). C&S Antennas Ltd. u.h.f panel antenna working on the skeleton slot principle. (Figure 3).
(b) Band 2 (610–960MHz). Siemens dipole array. (Figure 4).
(c) Band 3 (1350–1850MHz). Siemens corner reflector. (Figure 5).

The antenna feeder being used is a ½in coaxial cable made by Kabel Metall of the Federal Republic of

Figure 3. C&S Antennas Ltd – Panel Antenna for Band 1

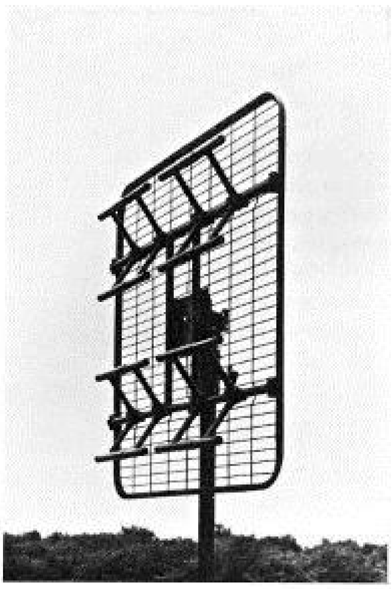

Figure 4. Siemens – Stacked dipole array antenna for Band 2.

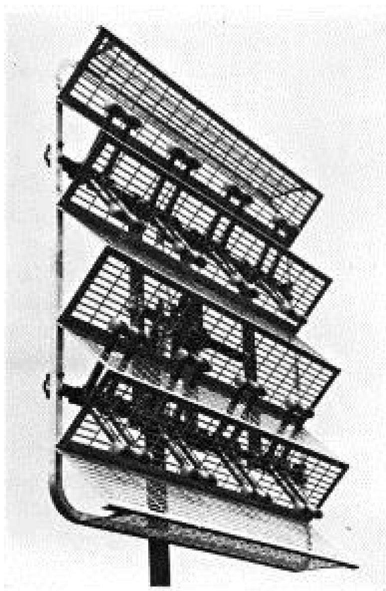

Figure 5. Siemens – corner reflector antenna for Band 3

Germany. It is fitted with the Spinner 4/11 connector which has a bayonet fitting and tap-type screw head. These will be issued in standard 16m lengths.

SYSTEM PERFORMANCE OF THE RADIO EQUIPMENT

Equipment system performance is specified by measuring the total attentuation between transmitter and receiver for a bit error rate of 1 in 10^5 (traffic) or 1 in 10^3 (c.o.w). Typical figures are shown below. Figures are adjusted to correspond to transmitter powers of 10W (Band 1, Band 2), 1.5W (Band 3). Receiver noise figure is 7.5dB (Bands 1, 2 and 3).

SYSTEM PERFORMANCE

Band	Bit Rate	Bit Error Rate	System Figure
Band 1	250 kbt/s	1 in 10^5	138.5dB
	500 kbt/s	1 in 10^5	131.5dB
Band 2	250 kbt/s	1 in 10^5	137.5dB
	500 kbt/s	1 in 10^5	130.5dB
Band 3	250 kbt/s	1 in 10^5	127.5dB
	500 kbt/s	1 in 10^5	121.0dB

Maintenance aids

MAINTAINABILITY

Great importance has been attached to the maintainability of TRIFFID, which consequently has a considerable amount of built-in test equipment (BITE) incorporated into its design. The TRIFFID radio has been provided with comprehensive facilities to enable quick and simple confirmation of correct operation and to assist in fault detection and location.

RELIABILITY

Particular attention has been paid to designing for high reliability. The predicted MTBF calculated by MIL217B for a complete stack is over 900 hours. To maximize availability of the equipment a low fault location and repair time is required. Specific guidelines were laid down by Ministry of Defence with respect to fault finding which were as follows:

(a) Fault diagnosis by the operator should be within two minutes to unit level using BITE.

(b) Repair by replacement of the faulty unit should be completed within ten minutes.

These times are achieved using BITE and with the addition of certain substitution modules and a mean active repair time of 35 minutes is obtained for the faulty unit.

SYSTEM UNIT

Each unit has its own BITE, but that provided on the Systems Unit is of particular interest.

(a) Monitoring on the Systems Unit provides visible and audible alarms for ten conditions (eight fault conditions and two normal conditions) detectable inside the Systems Unit. The visible alarms are presented on a mimic diagram which is arranged to show the flow of signals through the Systems Unit in both directions. The mimic diagram can be seen in the middle of the Systems Unit in figure 1.

(b) The Systems Unit contains a test pattern generator which is used for setting up links and system fault finding off-traffic.

(c) The test pattern generator generates a pseudo-random sequence (2^{15}—1) digits long. This pattern can be transmitted over a radio link or back towards the multiplexer. From there it can be turned round and returned to its point of origin where bit errors are counted and displayed. The pattern may also be turned round locally at r.f. This mode is used particularly for fault finding down to unit level and, in the field repair vehicle, for fault finding down to module level. When the test pattern is being transmitted from a remote station and the local equipment is used to turn the pattern round to the remote station, the bit error rate of the pattern passing through the local station can again be monitored as an aid to diagnosis of system faults.

(d) Traffic switching for pattern testing is performed by digital switches. The condition of the system and the result of the digital switching is also shown by the mimic diagram. Various symbols denote the break in normal traffic pattern synchronization, turn-round connections and bit error rate being measured.

Vehicle installations

TRIFFID will be mounted in both wheeled and tracked vehicles and figure 6 shows the 4-ton Bedford Mk wheeled version of the BRUIN installation as submitted to user trials. It is expected that a number of changes as a result of these trials will be made prior to production of the installation. The top of the 12m rear-mounted pneumatic mast (driven by the vehicle compressor) can be seen above the container. The power pallet is mounted forward of the container and has fitted the two 3kVA generators as well as the power conditioning unit and the batteries for both the radios and the generators. The pallet also carries two 400m drums of quad cable, a second stowed mast, antennas and coaxial feeder for each r.f head and miscellaneous other equipment such as generator fuel cans, water cans and fire extinguishers. This provides a self-contained radio relay detachment which would normally be manned by two men who could operate independently for a number of days without resupply, but which could be single-manned for limited periods.

At an early stage the vehicle and the installation were looked upon as essential elements in the radio station package as delivered to the user, and it was appreciated that the basic radio equipment would be enhanced or marred by the quality of the installation.

The installation contractor was therefore tasked to design an installation which, like the equipment it contained, would not only be suitable for BRUIN, but with the addition of extra equipments would also meet the full design requirements of PTARMIGAN. The conversion from BRUIN to PTARMIGAN (*i.e* the addition of extra equipments such as the s.h.f radio

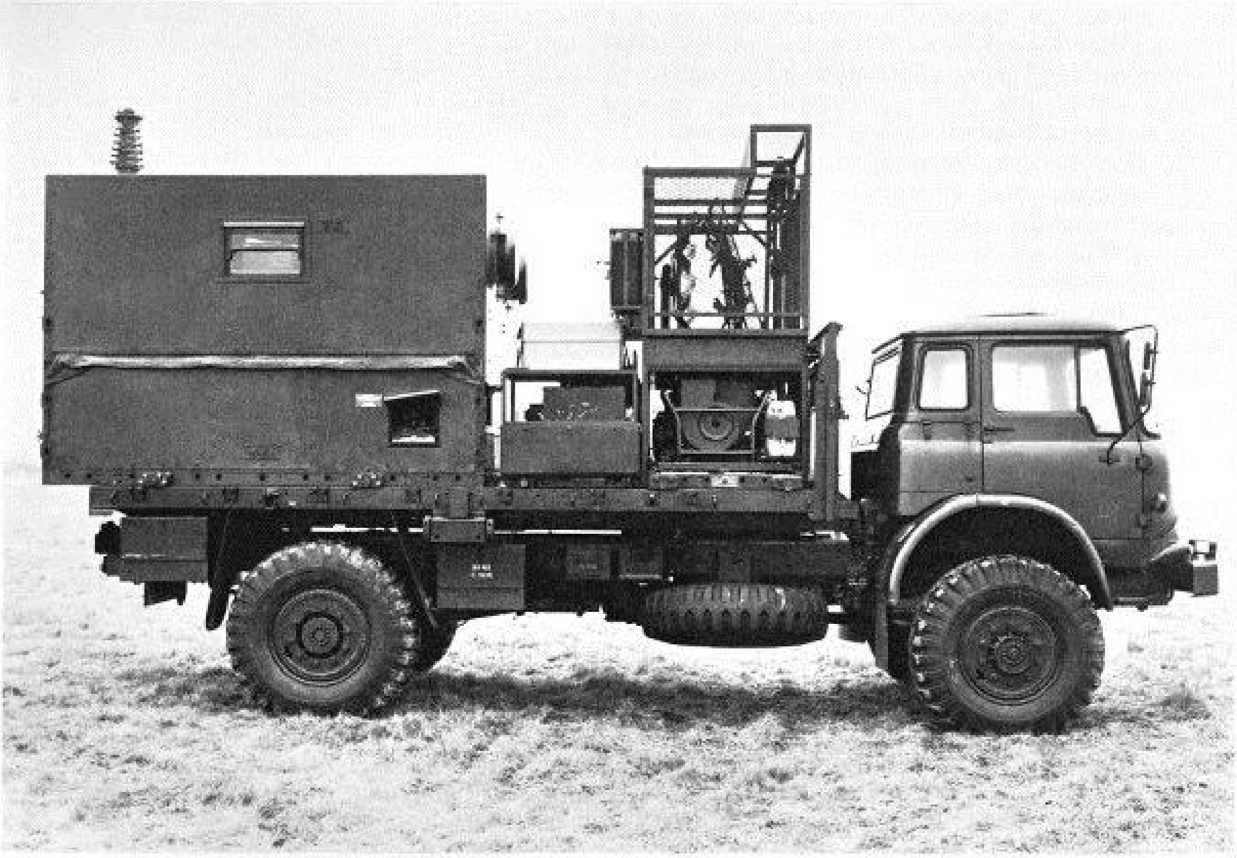

Figure 6. Bedford – Mk installation for BRUIN

relay and the more complex modem and e.o.w unit replacing the BRUIN l.t.u and e.o.w) will be carried out in the field.

The installation represents an integrated system. The layout of equipment both internally and externally is ergonomically designed for efficient operation in battle conditions. One significant improvement over previous vehicle installations is that remoting facilities have been provided to permit one-man operation. In addition to the operator's handset and alarms to notify changes in transmit level, feeder continuity and frequency separation, all of which can be remoted up to 15m, there is a remote input level meter to enable one man to swing the antenna for maximum receive signal (figure 7).

The contractor for the installations is Airtech Ltd. with, in this case, MCSL acting as their sub-contractor providing consultation on aspects directly relating to equipment performance. MCSL took part in the production of a detailed design specification for the installation and also played an active role in its testing prior to handover to MOD.

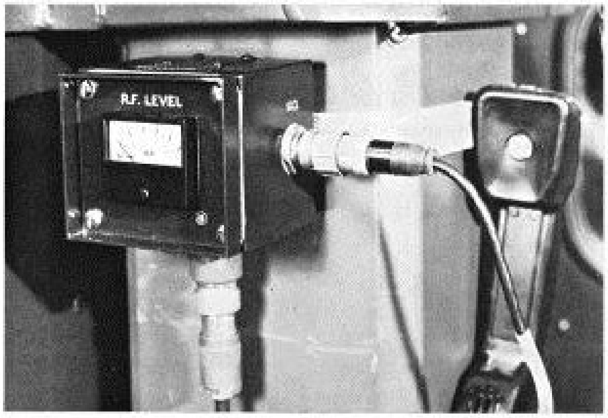

Figure 7. Remote r.f level meter mounted on SCAM pneumatic mast base. Operator's remote handset also shown

Conclusion

Marconi Communication Systems' TRIFFID will not only act as the main radio relay bearer for the incoming PTARMIGAN system, but more immediately it will enrich the British Army's already proven BRUIN tactical trunk communication system, particularly in terms of path loss capability and frequency manageability. Its inherent reliability and its ease of maintenance will also make significant contributions to the overall system effectiveness of BRUIN, whilst its simplicity of operation and its compactness when vehicle mounted will help ease the manpower overstretch problem. TRIFFID is eagerly awaited by the army in the field.